Topic E – Enviro Chemistry Part 5 – Dissolved Oxygen in Water

IB Chemistry

Topic E – Enviro

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E5 Dissolved oxygen in water - 1.5 hours

- E.5.1 Outline biochemical oxygen demand (BOD) as a measure of oxygen demanding wastes in water. (2)
- E.5.2 Distinguish between aerobic and anaerobic decomposition of organic material in water. (2) *Use redox equations as appropriate.*
- E.5.3 Describe the process of eutrophication and its effects. (2)
- E.5.4 Describe the source and effects of thermal pollution in water. (2)

E5.1 – Biochemical Oxygen Demand

- E.5.1 Outline biochemical oxygen demand (BOD) as a measure of oxygen demanding wastes in water. (2)
- **Biochemical Oxygen Demand** (BOD) describes the quantity of oxygen used when the organic material in the water is decomposed by microorganisms.

E5.1 - $[O_2]$

- The solubility of $O_2(g)$ in water is quite low
  - 8.3—— (ppm) at 25°C
  - Solubility can be altered by changes in temperature, concentrations of dissolved materials, and quantitates of biological waste
  - If the $[O_2]$ falls below 5 ppm fish will start to die
  - If the $[O_2]$ falls below 3 ppm fish cannot survive

E5.1 – Biological Wastes

- **Anthropogenic Biological wastes**
  - Human and animal waste (sewage/manure)
  - Food processing factory waste
  - Slaughterhouses
  - Paper mills
- Organic material will gradually decay by the action of microorganisms. It consumes O_2 as:
  - $(CH_2O)_n(aq) + nO_2(g) \rightarrow nCO_2(g) + nH_2O(l)$
  - $(CH_2O)_n$ is an empirical formula representing carbohydrates such as cellulose which form the structure of plants

E5.1 – BOD Values

- The previous process, **$(CH_2O)_n(aq) + nO_2(g) \rightarrow nCO_2(g) + nH_2O(l)$,** is called aerobic decomposition, as the microorganisms involved require O_2. As decay occurs, the O_2 available for other organisms such as fish is decreased
- **Biochemical Oxygen Demand** (BOD) describes the quantity of O_2 used when the organic material in the water is decomposed by microorganisms.
  - **Small BOD** = small amount of organic matter present, water is quite pure
  - **Large BOD** = impure water, much of the O_2 present is used up in decomposition, less for fish

E5.1 – BOD Values

- BOD [pure water] ≈ 1 ppm
- BOD [polluted water] > 5 ppm
- The [H_2O] at 25°C ≈ 8 ppm, if the BOD is 5 ppm it lowers the [O_2] ≈ 3 ppm where it can no longer sustain fish
- BOD values can be measured using a dissolved oxygen probe or via a redox titration

E5.2/3 – Decomposition of Organics and Eutrophication

- E.5.2 Distinguish between aerobic and anaerobic decomposition of organic material in water. (2) *Use redox equations as appropriate.*
- E.5.3 Describe the process of eutrophication and its effects. (2)

E5.2/3 - Eutrophication

- **Eutrophication** is defined as 'an increase in the level of chemical nutrients in an ecosystem.' However the terms if often used to mean the resultant increase in plant growth, lowering of $[O_2]$ and decline of fish populations
- **Lake environments typically favor fish over plant life**
  - Because levels of P and N are low, which results in limited plant growth and little decaying vegetation
  - Lake water has a low BOD, therefore fish populations are able to reach a high level!

E5.3 – Algal Bloom

- Human activities can lead to increases of nutrients in rivers and streams.
  - Use of fertilizers on farmland
  - Release of sewage onto rivers
- Both result in a large **increase in [nutrient],** and phosphorus in particular in the water they feed
- This excess of nutrients leads to excess growth of primitive plants called algae, which float on the surface of the water, a 'green scum' known as an **algal bloom**
  - The turbidity (cloudy) in the water increases

E5.2/3 – Algal Bloom

- **Eutrophic lakes** can be recognized by a green tint to the water

E5.2/3 – Algal Bloom

- Algae blooms result in unpleasant tasting water and may release harmful toxins even
- The color, taste, and toxicity of the water affect human activities such as fishing and boating
- Water clogged with algae is more difficult to treat for drinking
- **Biggest problem is AFTER the algae die**
  - Dead algae is consumed by aerobic bacteria which use up the dissolved O_2 in the water
  - $[O_2]$ falls below necessary level, only material like sludgeworms can survive. Lake is nearly useless for fishing and has an effect on local communities

E5.2/3 – Algal Bloom

- After the algal bloom, [O_2] falls so low that aerobic bacteria cannot survive
- Instead, anaerobic bacteria decompose the remaining dead algae, forming foul-smelling products such as ammonia, hydrogen sulfide, methane and thioalcohols
  - Bacteria may release dangerous toxins lethal to animals

E5.4 – Thermal Pollution

- E.5.4 Describe the source and effects of thermal pollution in water. (2)
- The temperature of water highly affects the solubility of gases.
  - At 25^{o}C the solubility is 8.3 ppm
  - At 30^{o}C this falls to 5 ppm when fish begin to die

E5.4 – Thermal Pollution

- Human activities can lead to an increase in water temperature known as **thermal pollution**
- This occurs near power stations where water is drawn to cool the steam from the turbines in devices called heat exchangers. When water leaves it could be 20^{o}C warmer
- [O_2] is decreased when temperature rises because
  - Solubility of O_2 is decreased with lower Temps
  - Microorganisms respire more quickly

E5.4 – Thermal Pollution

- High temperatures also cause enzymes in microorganisms to denature and as a result they cannot digest their food molecules
- Changing temperatures may also alter the cycle of fish such as:
  - Spawn (lay eggs) earlier
  - Eggs hatch earlier
  - At this time in the cycle the necessary nutrients may not be available in the system
  - Thermal pollution may also be **cooling** due to cold water at the bottom of reservoirs released into streams below